LEVEL

12

ADA059314

DDC FILE COPY

NAMRL-1247

INFLUENCE OF A VISUAL DISPLAY AND FREQUENCY OF WHOLE-BODY ANGULAR OSCILLATION ON INCIDENCE OF MOTION SICKNESS

Fred E. Guedry, Jr., Alan J. Benson, and H. Jack Moore

June 1978

NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FLORIDA

Guedry, F. E., Jr. 1978
A. J. Benson, H. J. Moore

INFLUENCE OF A VISUAL DISPLAY AND FREQUENCY OF WHOLE-BODY ANGULAR OSCILLATION ON INCIDENCE OF MOTION SICKNESS. NAMRL-1247. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 22 June.

Disadvantageous aspects of the vestibulo-ocular reflex may emerge in aircraft or other motion platforms when visual tasks center on displays that are fixed relative to the observer. In this circumstance the reflex may drive the eyes relative to the display, thereby degrading vision and sometimes inducing motion sickness. This report is one of a series of investigations elucidating stimulus conditions that influence the probability of nauseotypic disturbance during visual-vestibular interactions.

Visual search within a head-fixed display consisting of a 12 x 12 digit matrix is degraded by whole-body angular oscillation at 0.02 Hz (peak velocities ±155 deg/sec) and signs and symptoms of motion sickness are prominent in a number of individuals within a 5-minute exposure. Exposure to 2.5 Hz (±20 deg/sec peak velocity) produces equivalent degradation of the visual search task but does not produce signs and symptoms of motion sickness within a 5-minute exposure.

Motion sickness
Stimulus frequency
Visual-vestibular interaction
Vestibular function
Visual function

Guedry, F. E., Jr. 1978
A. J. Benson, H. J. Moore

INFLUENCE OF A VISUAL DISPLAY AND FREQUENCY OF WHOLE-BODY ANGULAR OSCILLATION ON INCIDENCE OF MOTION SICKNESS. NAMRL-1247. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 22 June.

Disadvantageous aspects of the vestibulo-ocular reflex may emerge in aircraft or other motion platforms when visual tasks center on displays that are fixed relative to the observer. In this circumstance the reflex may drive the eyes relative to the display, thereby degrading vision and sometimes inducing motion sickness. This report is one of a series of investigations elucidating stimulus conditions that influence the probability of nauseotypic disturbance during visual-vestibular interactions.

Visual search within a head-fixed display consisting of a 12 x 12 digit matrix is degraded by whole-body angular oscillation at 0.02 Hz (peak velocities ±155 deg/sec) and signs and symptoms of motion sickness are prominent in a number of individuals within a 5-minute exposure. Exposure to 2.5 Hz (±20 deg/sec peak velocity) produces equivalent degradation of the visual search task but does not produce signs and symptoms of motion sickness within a 5-minute exposure.

Motion sickness
Stimulus frequency
Visual-vestibular interaction
Vestibular function
Visual function

Guedry, F. E., Jr. 1978
A. J. Benson, H. J. Moore

INFLUENCE OF A VISUAL DISPLAY AND FREQUENCY OF WHOLE-BODY ANGULAR OSCILLATION ON INCIDENCE OF MOTION SICKNESS. NAMRL-1247. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 22 June.

Disadvantageous aspects of the vestibulo-ocular reflex may emerge in aircraft or other motion platforms when visual tasks center on displays that are fixed relative to the observer. In this circumstance the reflex may drive the eyes relative to the display, thereby degrading vision and sometimes inducing motion sickness. This report is one of a series of investigations elucidating stimulus conditions that influence the probability of nauseotypic disturbance during visual-vestibular interactions.

Visual search within a head-fixed display consisting of a 12 x 12 digit matrix is degraded by whole-body angular oscillation at 0.02 Hz (peak velocities ±155 deg/sec) and signs and symptoms of motion sickness are prominent in a number of individuals within a 5-minute exposure. Exposure to 2.5 Hz (±20 deg/sec peak velocity) produces equivalent degradation of the visual search task but does not produce signs and symptoms of motion sickness within a 5-minute exposure.

Motion sickness
Stimulus frequency
Visual-vestibular interaction
Vestibular function
Visual function

Guedry, F. E., Jr. 1978
A. J. Benson, H. J. Moore

INFLUENCE OF A VISUAL DISPLAY AND FREQUENCY OF WHOLE-BODY ANGULAR OSCILLATION ON INCIDENCE OF MOTION SICKNESS. NAMRL-1247. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 22 June.

Disadvantageous aspects of the vestibulo-ocular reflex may emerge in aircraft or other motion platforms when visual tasks center on displays that are fixed relative to the observer. In this circumstance the reflex may drive the eyes relative to the display, thereby degrading vision and sometimes inducing motion sickness. This report is one of a series of investigations elucidating stimulus conditions that influence the probability of nauseotypic disturbance during visual-vestibular interactions.

Visual search within a head-fixed display consisting of a 12 x 12 digit matrix is degraded by whole-body angular oscillation at 0.02 Hz (peak velocities ±155 deg/sec) and signs and symptoms of motion sickness are prominent in a number of individuals within a 5-minute exposure. Exposure to 2.5 Hz (±20 deg/sec peak velocity) produces equivalent degradation of the visual search task but does not produce signs and symptoms of motion sickness within a 5-minute exposure.

Motion sickness
Stimulus frequency
Visual-vestibular interaction
Vestibular function
Visual function

Approved for public release; distribution unlimited.

INFLUENCE OF A VISUAL DISPLAY AND FREQUENCY OF WHOLE-BODY ANGULAR OSCILLATION ON INCIDENCE OF MOTION SICKNESS.

(10) Fred E. Guedry, Jr., Alan J. Benson [redacted] H. Jack Moore

(16) F51524

(9) Interim rept.

Naval Medical Research and Development Command
(17) ZF51 524 004-9022

(14) NAMRL-1247

Approved by

Ashton Graybiel, M.D.
Assistant for Scientific Programs

Released by

Captain R. E. Mitchell, MC USN
Commanding Officer

(12) 17p

(11) 22 Jun[redacted]78

NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
NAVAL AIR STATION
PENSACOLA, FLORIDA 32508

406 L

SUMMARY PAGE

THE PROBLEM

Disadvantageous aspects of the vestibulo-ocular reflex may emerge in aircraft or other motion platforms when visual tasks center on displays that are fixed relative to the observer. In this circumstance the reflex may drive the eyes relative to the display, thereby degrading vision and sometimes inducing motion sickness. This report is one of a series of investigations elucidating stimulus conditions that influence the probability of nauseotypic disturbance during visual-vestibular interactions.

FINDINGS

Visual search within a head-fixed display consisting of a 12 x 12 digit matrix is degraded by whole-body angular oscillation at 0.02 Hz (peak velocities $\pm$ 155 deg/sec), and signs and symptoms of motion sickness are prominent in a number of individuals within a 5-minute exposure. Exposure to 2.5 Hz ($\pm$20 deg/sec peak velocity) produces equivalent degradation of the visual search task but does not produce signs and symptoms of motion sickness within a 5-minute exposure.

Dr. Benson is Head of the Behavioral Sciences Division, RAF Institute of Aviation Medicine, Farnborough, Hants, England.

INTRODUCTION

Natural whole-body movement such as walking, running, and jogging produces complex head oscillations with high-frequency components that exceed the capability of the visual tracking system to stabilize the eye relative to the Earth (4-6), but the vestibulo-ocular reflex working in concert with the visual system provides the degree of ocular stabilization needed to sustain clear vision. Disadvantageous aspects of this reflex may emerge in aircraft or other motion platforms, especially when visual tasks center on displays that are fixed relative to the observer. In this circumstance the reflex may drive the eyes relative to the display with two potentially unfavorable results, degradation of vision and nausea. This report is primarily concerned with the nauseogenic effects that sometimes accompany this form of conflictual visual-vestibular interaction.

Low-frequency (0.02 - 0.04 Hz) high peak velocity angular oscillation in yaw about an Earth-vertical rotation axis produces a predictable sinusoidal variation of vestibular nystagmus (6,12). As a result of effective visual suppression of the vestibulo-ocular reflex during low-frequency vestibular stimuli (5), high peak velocities of low-frequency body oscillation are required for the vestibulo-ocular reflex to blur vision of most subjects for head-fixed displays. When requisite peak stimulus velocities are used, then these sinusoidal stimuli produce a cyclic variation in visual performance which is predictable from fairly well established stimulus-response relationships. It has recently been found that such stimuli may be highly nauseogenic, but only when subjects are concomitantly presented with certain visual displays and tasks (10,19).

The gain of the vestibulo-ocular reflex (ratio of peak eye velocity to peak stimulus velocity) is greater with high-frequency (2 - 10 Hz) than with low-frequency sinusoidal semicircular canal stimuli, and, moreover, visual suppression of the vestibulo-ocular reflex during these high-frequency stimuli is relatively ineffectual (5). Thus with high-frequency vestibular stimuli, low amplitudes and low peak velocities are sufficient to blur vision for head-fixed displays. This, of course, is of considerable practical significance from the standpoint of vision in dynamic environments, but the point of the present study is to determine whether or not these high-frequency vestibular stimuli are also nauseogenic to subjects when they are presented with a visual display and task which are known to cause nausea with the low-frequency stimuli.

PROCEDURE

SUBJECTS

The present paper compares visual performance and signs of sickness produced in several groups of subjects exposed to motion stimuli. One group, 25 staff members, 6 females and 19 males (mean age 29.8 years), of the RAF Institute of Aviation Medicine, Farnborough, England, were exposed to high-frequency whole-body oscillation while scanning a visual display. Results from this group are compared with results from 51 naval aviation officer candidates, Naval Air Station, Pensacola, Florida, (mean age

about 25 years) who were exposed to low-frequency whole-body angular oscillation while viewing an identical visual display. Details about additional comparison groups exposed to the low-frequency motion stimulus will be presented below.

APPARATUS

Subjects, seated at the center of a rotation device, viewed a 12 x 12 character matrix (Figure 1) with alpha numeric coordinates. The square matrix measures 165 x 165 mm and subtends approximately a 0.2 x 0.2 rad (12°) visual angle; white margins around the matrix increase the visual angle of the entire display to 0.3 x 0.3 rad (17°). The display has a white card luminance of 0.34 cd/m^2 (0.1 fL), and it was fixed at eye level on the rotation device and viewed against a black cloth background which enclosed the rotary structure and excluded external visual reference.

Matrix coordinates were recorded on audio tape at 7-second intervals to provide commands for the subject to retrieve information from the display. The subject's task was to locate the matrix position and to name the digit in that position and the next two digits below it in the same column.

Subjects were given 3 minutes of practice on the data retrieval task with the turntable stationary. Then after a short rest, a 5-minute period of angular oscillation was commenced in which subjects again performed the data retrieval task. One group (N = 25) was exposed to angular oscillation in yaw at 2.5 Hz with peak angular velocities of ±20 deg/sec (0.35 rad/sec). During a 315-second exposure, commands for locating 45 coordinates were presented. The comparison group (N = 51) was oscillated in yaw at 0.02 Hz with peak angular velocities of ±155 deg/sec (2.71 rad/sec). During 300 seconds of oscillation, commands for locating 42 coordinates were presented.

RESULTS

VISUAL PERFORMANCE

Performance of the two groups under static conditions, 3 minutes of data retrieval from the matrix while stationary, was closely matched. The group later exposed to high-frequency oscillation correctly identified 97.2 percent of the total number of digits to be identified. The group later exposed to low-frequency oscillation correctly identified 98 percent of the total number of digits to be identified.

Performance of the two groups during the 5 minutes of angular oscillation was also closely matched. Subjects exposed to high-frequency oscillation correctly named 60.2 percent of 135 digits (in 315 seconds) to be identified while subjects exposed to 5 minutes of low-frequency oscillation correctly named 58.0 percent of 126 digits* to be identified. There were pronounced intersubject differences in the number of correctly identified digits during the 5 minutes of oscillation in both groups, but the coefficients

*Exactly 300 seconds of oscillation permitted only 42 taped commands.

	A	B	C	D	E	F	G	H	I	J	K	L
1	7	1	1	8	2	4	3	1	6	6	9	4
2	6	4	4	2	4	3	1	8	9	7	4	1
3	2	2	3	4	7	8	6	5	1	4	8	5
4	9	9	5	4	6	2	7	3	8	3	7	9
5	8	1	4	3	6	5	7	7	1	4	2	6
6	7	4	7	1	8	1	9	6	3	2	8	5
7	1	7	6	7	6	4	9	5	4	8	3	7
8	7	1	3	3	4	8	9	4	2	5	6	8
9	6	2	1	6	7	3	8	9	7	2	6	6
10	1	7	5	9	9	1	5	6	6	3	5	8
11	9	3	6	7	3	2	2	8	4	5	2	5
12	2	7	6	2	9	9	3	4	1	5	1	7

Figure 1

Alpha Numeric Display for Visual Task

of variation (the ratio of the standard deviation to the mean) were identical (0.40) for the two groups.

There was, however, one important difference in the visual performance of the two groups during oscillation. During high-frequency oscillation there was no consistent change in visual performance during the 5-minute exposure, although some subjects did exhibit an irregular fluctuation in their ability to locate and see targets during the period of oscillation. In contrast, during low-frequency oscillation, errors in visual performance peaked at 25-second intervals, near the peak stimulus angular velocities, as would be expected from known variations in vestibular nystagmus during angular oscillation of 0.02 Hz.

INDICES OF MOTION SICKNESS

Subjects in both groups were rated for signs and symptoms of motion sickness, and they also rated themselves for stomach awareness, malaise, and nausea. The observer's rating of subjects for signs of disturbance by motion was based upon a procedure used in previous studies (1) to evaluate effects of a sequence of Coriolis cross-coupled vestibular stimuli administered within a 5-minute interval. Items specifically rated were pallor, sweating, facial expression, steadiness, signs of disorientation, and recovery rate. An over-all rating was also included and this was influenced by factors such as the subject's comments, carriage (postural signs), failure to complete the test, and general demeanor.

Ratings given to the group exposed to high-frequency oscillation indicated that this motion condition did not produce convincing signs of motion sickness. Pallor (and/or flushing) was not evident in any subject; a minor degree of sweating occurred, but no more than would occur from thermal effects in the enclosed rotary structure. There was evidence of mild to moderate unsteadiness in some of the subjects immediately after the 5-minute exposure. All of the subjects in this group completed the experiment, and their self-ratings substantiated the observer's rating of little or no signs of sickness. Self-rate items included like/dislike, stomach awareness, post-test dizziness, nausea (sickness feelings), and feeling hot (or cold). Negative comments from subjects centered on the difficulty in performing the assigned task due to difficulty in seeing the display. Only 2 of the 25 subjects reported any degree of stomach awareness or nausea, and neither of these appeared ill to the observer. On a 1 to 7 rating scale, the group mean self-rate for stomach awareness was 1.2 (1.0 corresponds to no effect and 7.0 to very strong effect), and the mean self-rate for nausea was 1.1.

By contrast, the group exposed to low-frequency oscillation gave ample evidence of motion sickness, but as is common in all conditions that produce nausea and sickness in the course of a short exposure, signs and symptoms of disturbance from this stimulus condition were subject to pronounced individual differences. Six of the 51 subjects failed to complete 5 minutes of exposure to the motion stimulus. Of these 6 subjects, 4 vomited, 1 retched, and the remaining subject withdrew very early in the motion exposure, apparently due to fear of sickness, but too soon to have become sick. The

group mean self-rate for stomach awareness was 3.0 and for nausea it was 2.7 (as compared with 1.2 and 1.1, respectively, for these self-ratings in the high-frequency oscillation group). On one or the other of these two self-rate items, 75 percent of this group indicated some degree of disturbance, whereas in the high-frequency oscillation group, only 8 percent of the subjects indicated some degree of disturbance. Table I compares the self-ratings of the two groups. Only in the like/dislike rating were the two groups nearly equal, and on this item individuals exposed to high-frequency oscillation complained of difficulty in seeing the display, whereas individuals in the other group complained of sickness as well as difficulty in seeing the display.

Table I

Comparison of Self-ratings: Percent Indicating No Effect, and Percent Aborting Test in the Two Groups

	0.02 Hz ±155 deg/sec			2.5 Hz ±20 deg/sec		
Item Rated	Mean	SD	Percent Indicating No Effect	Mean	SD	Percent Indicating No Effect
Stomach awareness	3.0	1.94	27	1.2	0.79	92
Nausea and sickness	2.7	1.97	39	1.1	0.62	92
Like/dislike	3.7	1.80	16	3.2	1.13	4
Dizziness	2.6	1.60	25	1.1	0.11	88
Feeling hot or cold	2.6	2.13	55	1.6	1.16	68
Percent aborting test		12			0	

Other groups of subjects exposed to the same low-frequency stimulus and visual task have yielded results similar to those of the low-frequency group in the present study. A group of 51 naval aviation officer candidates achieved a 60 percent digit identification and had a mean self-rate on nausea and stomach awareness items of 3.1, and of these 51 subjects, 6 withdrew ($\approx$ 12 percent) from the motion condition because of nausea and/or vomiting (21). Another group of 304 naval flight officer candidates had a 59 percent rate of correct digit identification and a mean self-rate of 2.8 on the nausea and stomach awareness items (16). Thirty-five individuals (11.5 percent) withdrew because of sickness.

The provocative nature of this low-frequency high peak velocity stimulus, when it is combined with the visual search task, may be appreciated by comparing its effects with those produced when the same students were exposed on another day to a sequence of ten Coriolis cross-coupled stimuli over a 5-minute interval induced by 45-degree head movements during whole-body rotation at 90 deg/sec (16,21). Such stimuli are commonly regarded as highly provocative of motion sickness, yet the mean rating on stomach awareness and nausea was 2.4 (as compared with 2.8), and only 3 percent

(as compared with 11.5 percent) withdrew from the 5-minute exposure to cross-coupled stimuli.

DISCUSSION

The salient feature of the present study is that visual data acquisition from a head-fixed complex display was degraded equally by high-frequency low peak velocity whole-body oscillation or by low-frequency high peak velocity whole-body oscillation, but only the low-frequency oscillation produced substantial signs and symptoms of motion sickness. That the latter condition coupled with the visual data retrieval task is consistently nauseogenic to the degree observed in the present study has been substantiated by a number of subsequent observations (15,16). Substantiating data from other groups are not available for results of the high-frequency oscillation, although the absence of signs and symptoms of sickness in the group so exposed in the present study was striking. It seems unlikely that a slight mean age difference between groups would account for the substantial difference in the incidence of symptoms, especially since some of the individuals in the older group, those exposed to the high-frequency stimulus, were exposed on other occasions to a similar visual task during low-frequency stimulation and became sick within 5 minutes. With slight reservations, then, we must conclude that high-frequency oscillation sufficient to degrade performance with this visual task is not nauseogenic in the course of a 5-minute exposure, whereas a low-frequency oscillation that produces a comparable decrement in visual performance is nauseogenic.

The 0.02 Hz stimulus, which in regard to visual performance may be considered a 0.04 Hz stimulus because there were two periods of degraded vision in each cycle, is, by either reckoning, a frequency which is far below the frequency range sometimes indicated as being effective in producing motion sickness (17,20). Of course, the form of motion input in our study differs from that of most studies seeking to elucidate frequency effects. However, the motivation to look for "the provocative frequency" probably stems from the idea that maximum response gain occurs at the natural frequency of some responding component or components, such as the otolith organs, the stomach, or the semicircular canals, et cetera. Yet the present results show that motion sickness production was least at a frequency (2.5 Hz) where the vestibulo-ocular response gain may be greatest (cf. Benson and Barnes, 6). This observation illustrates the fact that the determination of stimuli that produce motion sickness is complex and will not be solved by simply searching for the "natural frequency" of any one responding system, although such information will undoubtedly be useful in unraveling the remaining mysteries of motion sickness.

The impairment of visual performance during angular oscillation can be accounted for by a failure to suppress vestibulo-ocular responses and the consequent movement of the retinal image. Typical features of the oculomotor response to the low- and high-frequency stimuli are illustrated by Figures 2 and 3. The upper traces labeled "A" were recorded in darkness with no matrix display visible; the lower traces labeled "B" were obtained with the display illuminated and the subject performing the visual task.

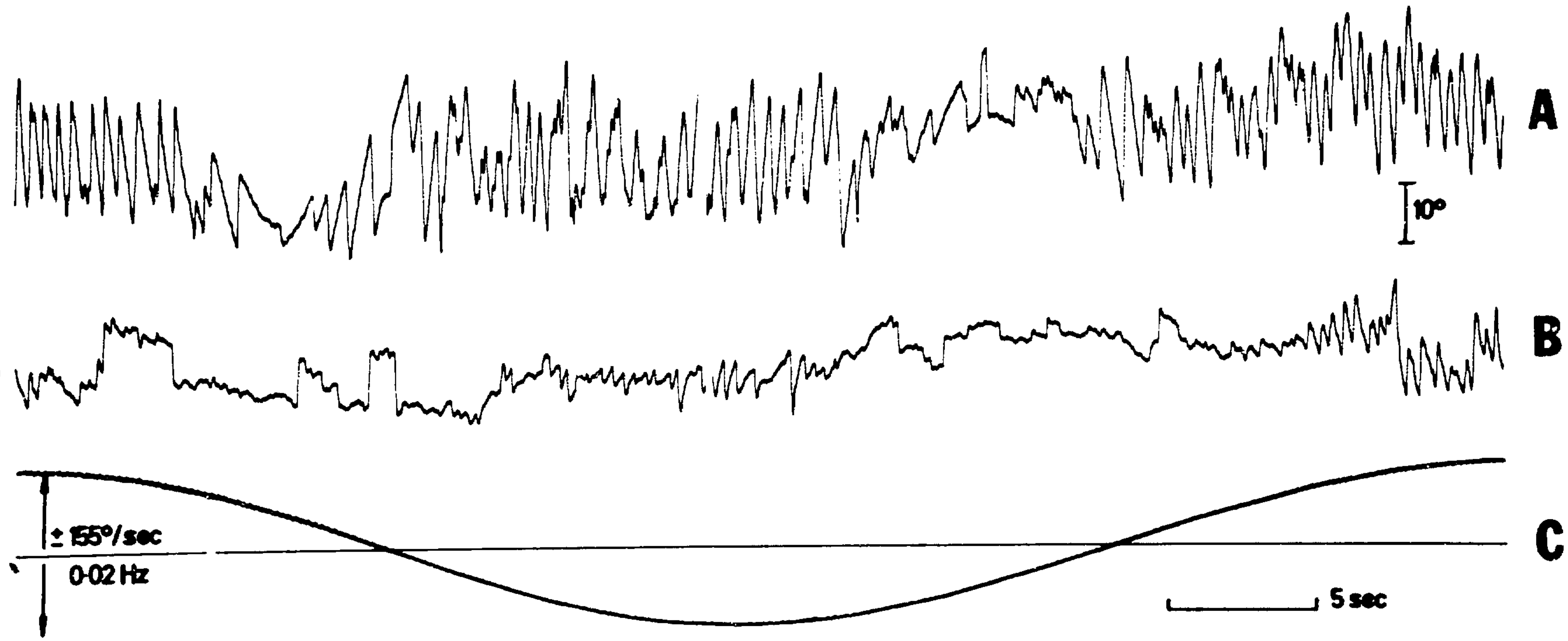

Figure 2

Comparison of vestibulo-ocular reflex in dark (A) and with visual suppression (B) during low-frequency (0.02 Hz) sinusoidal change in turntable velocity (C). A and B are eye position recordings and C is a recording of turntable velocity.

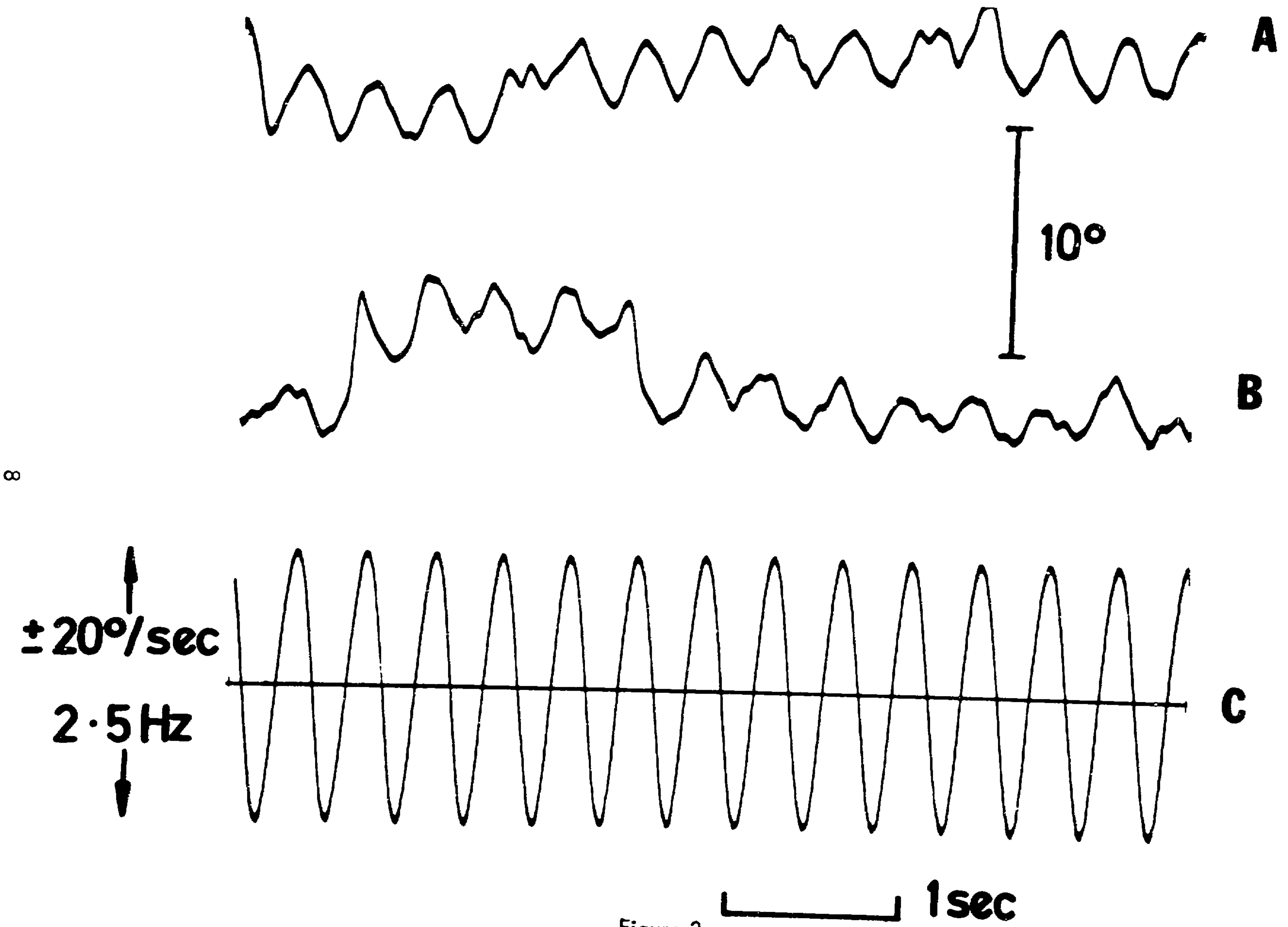

Figure 3

Comparison of vestibulo-ocular reflex in dark (A) with visual suppression (B) *during high-frequency* (2.5 Hz) sinusoidal oscillation of the rotation device (C). A and B are eye position recordings and C is a recording of turntable velocity. *Note that there is very little* visual suppression at this stimulus frequency.

At 0.02 Hz the vestibulo-ocular response is characterized by a direction-changing nystagmus which, in the dark, has a slow phase velocity of approximately 60 percent of the angular velocity of the stimulus; i.e., peak slow phase velocity $\approx \pm 90$ deg/sec. In attempting to fixate on an element of the alpha numeric matrix, nystagmus slow phase velocity is substantially decreased; the peak slow phase velocity is reduced to $\approx \pm 30$ deg/sec, though a greater suppression of the response occurs during the remainder of each half of the stimulus cycle (7). The mean slow phase eye velocity during each half cycle is $\approx \pm 14$ deg/sec.

The eye movements induced by the high-frequency stimulus differ from those of the low-frequency response in two essential features: There is a relative absence of saccades, and there is little suppression on illuminating the display. At 2.5 Hz the vestibulo-ocular gain is close to unity and is reduced only by about 20 percent on attempting to fixate on a display which rotates with the head (5); so, in the high-frequency stimulus conditions the eye velocity peaks at $\approx \pm 16$ deg/sec and has a mean modulus velocity of ≈ 10 deg/sec.

The mean slow phase eye velocity in the two experimental conditions is therefore comparable and is sufficient to produce movement of the retinal image and hence a substantial impairment of visual acuity (9). Although the mean velocity was less in the high- than in the low-frequency oscillation condition, visual performance in the two experimental conditions was quite comparable. This apparently anomalous finding may be explained by differences in the temporal characteristics of the visual impairment produced by the two stimuli. At 0.02 Hz there is a period during each half cycle when the display could be read without difficulty (i.e., the nystagmus was essentially suppressed), which alternated with a period of severe loss of acuity. In contrast, at 2.5 Hz vision was continuously blurred, and the probability of identifying a character in the matrix was governed by its spatial coordinates rather than any temporal relationship to the stimulus cycle, as at low frequency.

The degradation of visual performance produced by a multi-turn low-frequency angular oscillation and by a small amplitude angular vibration can be accounted for by the known behavior of the vestibulo-ocular reflex and its suppression by the oculomotor pursuit system, but an explanation of why these two stimuli are so different in their nauseogenic properties is more covert; nevertheless, it behooves us to speculate on reasons for this disparity. It is known from other experiments that a low-frequency, high-intensity angular oscillation about the yaw axis does not induce sickness when experienced in darkness or when the subject fixates on a simple target which rotates with him (10). However, the same rotational stimulus induces nausea, and other signs and symptoms of motion sickness, when the subject is required to inspect a matrix of digits (10,19). Thus an essential feature of the provocative situation is the disruption of visual search and of the location of characters within a complex display by the vestibulo-ocular responses. But the present experiment has shown, without ambiguity, that it is only a low-frequency angular oscillation that is nauseogenic, although both the low- and high-frequency stimuli produced slow phase eye movements of comparable velocity and produced equal decrements in visual performance.

The difference in the vestibulo-ocular responses at the two frequencies used in the present study is (as noted above) that at 0.02 Hz, the oculomotor response consists of true nystagmic beats with definite slow and fast components, whereas at 2.5 Hz, the eye movement approximates to a smooth sinusoid. The few saccades present in Line B of Figure 3 (display illuminated) are probably voluntary saccades associated with visual search of the matrix.

The visual task employed was one that required the subject to look from one facet of the display to another in order to locate a spatial coordinate, a pattern of visual search that is characteristically achieved by saccadic eye movements between successive points of fixation (24). The presence of involuntary saccades of vestibular origin will, it is suggested, interfere with the voluntary saccades in such a manner that the eye position, and hence the retinal image, does not accord with that which the subject "expects" to be achieved by a particular voluntary saccade. With the high-frequency stimulus the vestibulo-ocular reflex produces only a "slow component" eye movement without saccades, so there is no disruption of voluntary saccades and no disparity in the spatial localization of the visual image between that which is modeled by neural centers and that which is achieved. The image is, of course, blurred in both experimental conditions by the presence of slow component eye movements. Slow component eye movements may have some influence on the precision of the voluntary saccades, but the limited evidence available suggests that this effect is small (4) and is of minor importance when compared with the disruptive effects of involuntary saccades.

An explanation of why the disruption by voluntary saccades causes the development of the motion sickness syndrome is a matter for further speculation. At one level of description, visual search during low-frequency oscillation may be identified as a condition in which visual cues about the subject's spatial relationship and movement do not accord with those that are "expected" on the basis of previous transactions in the natural environment. This condition, in which there is a rearranged sensory input and a mismatch between received and expected cues, is common to the many and diverse circumstances that cause motion sickness, and defines the essential nature of the nauseogenic stimulus (8,11,13,14,22).

At another level of description, the vestibular cerebellum may be identified as a structure involved in the control of saccadic eye movements and the induction of motion sickness. Removal of the lower vermis including the nodulus produces a degree of immunity to motion sickness (3,13,18), and lesions of the vermis produce dysmetria of saccadic eye movements (2) as well as alteration of the amplitude of the fast phase of vestibular nystagmus (23). Only the high peak velocity low-frequency stimulus sets off vestibular saccadic interference with voluntary saccadic movements, disrupting "automatic" control functions normally involving the vermis, which happens to be a crucial structure in motion sickness.

CONCLUSION

Visual search within a head-fixed display consisting of a 12 x 12 digit matrix is

degraded by whole-body angular oscillation at 0.02 Hz (peak velocities $\pm$155 deg/sec), and signs and symptoms of motion sickness are prominent in a number of individuals within a 5-minute exposure. Exposure to 2.5 Hz ($\pm$20 deg/sec peak velocity) produces equivalent degradation of the visual search task but does not produce signs and symptoms of motion sickness within a 5-minute exposure.

REFERENCES

1. Ambler, R. K., and Guedry, F. E., Reliability and validity of the Brief Vestibular Disorientation procedure compared under 10-rpm and 15-rpm conditions. Aerospace Med., 42:186-189, 1971.

2. Aschoff, J. C., and Cohen, B., Changes in saccadic eye movements produced by peripheral cortical lesions. Exp. Neurol., 32:123-133, 1971.

3. Bard, P., Woolsey, C. N., Snider, R. S., Mountcastle, V. B., and Bromiley, R. B., The limitation of central nervous mechanisms involved in motion sickness. Fed. Proc., 6:72, 1947.

4. Barnes, G. R., Vestibulo-ocular responses to head turning movements and their functional significance during visual target acquisition. Ph.D. Thesis, University of Surrey, Guildford, 1976.

5. Barnes, G. R., Benson, A. J., and Prior, A.R.J., Visual-vestibular interaction in the control of eye movement. Aviat. Space Environ. Med., 49:557-564, 1978.

6. Benson, A. J., and Barnes, G. R., Vision during angular oscillation: The dynamic interaction of visual and vestibular mechanisms. Aviat. Space Environ. Med., 49:340-345, 1978.

7. Gilson, R. D., Guedry, F. E., and Benson, A. J., Influence of vestibular stimulation and display luminance on the performance of a compensatory tracking task. Aerospace Med., 41:1231-1237, 1970.

8. Guedry, F. E., Psychophysiological studies of vestibular function. In: Neff, W. D. (Ed.), Contributions to Sensory Physiology, Volume I. New York: Academic Press, 1965. Pp 63-135.

9. Guedry, F. E., Relations between vestibular nystagmus and visual performance. Aerospace Med., 39:570-579, 1968.

10. Guedry, F. E., and Ambler, R. K., Assessment of reactions to vestibular disorientation stress for purposes of aircrew selection. AGARD-CP-109. London: Technical Editing and Reproduction, Ltd., 1973.

11. Guedry, F. E., and Correia, M. J., Vestibular function in normal and in exceptional conditions. In: Masterton, R. B. (Ed.), Handbook of Behavioral Neurobiology. New York: Plenum Press, 1978 (in press).

12. Hixson, W. C., and Niven, J. I., Frequency response of the human semicircular canals. II. Nystagmus phase shift as a measure of nonlinearities. NSAM-830. Pensacola, FL: Naval School of Aviation Medicine, 1962.

13. Kornhuber, H. H., The vestibular system and the general motor system. In: Kornhuber, H. H. (Ed.), Handbook of Sensory Physiology, VI/2. Berlin/Heidelberg/New York: Springer-Verlag, 1974. Pp 581-620.

14. Lansberg, M. P., A Primer of Space Medicine. Amsterdam/New York: Elsevier, 1960.

15. Lentz, J. M., and Guedry, F. E., Motion sickness susceptibility: A comparison of laboratory tests. NAMRL-1244. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 1977.

16. Lentz, J. M., Holtzman, G. L., Hixson, W. C., and Guedry, F. E., Normative data for two short tests of motion reactivity. NAMRL-1243. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 1977.

17. McCauley, M. E., Royal, J. W., Wylie, C. D., O'Hanlon, J. F., and Mackie, R. R., Motion sickness incidence: Exploratory studies of habituation, pitch, and roll, and the refinement of a mathematical mode. Technical Report 1733-2. Goleta, CA: Human Factors Research, Inc., Santa Barbara Research Park, 1976.

18. Money, K. E., Motion sickness. Physiol. Rev., 50:1-39, 1970.

19. Moore, H. J., Lentz, J. M., and Guedry, F. E., Nauseogenic visual-vestibular interaction in a visual search task. NAMRL-1234. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 1977.

20. O'Hanlon, J. F., and McCauley, M. E., Motion sickness incidence as a function of the frequency and acceleration of vertical sinusoidal motion. Aerospace Med., 45:366-369, 1974.

21. Prewitt, D. D., Interrelations between measures of motion history, personality, and immediate reactions to unusual motion stimuli. Master's Thesis, University of West Florida, Pensacola, 1975.

22. Reason, J. T., and Brand, J. J., Motion Sickness. London/New York: Academic Press, 1975.

23. Wolfe, J. W., Evidence for control of nystagmic habituation by folcum-tuber vermis and fustigial nuclei. Acta otolaryng. (Stockh.), Suppl. 231, 1968.

24. Yarbus, A. L., Eye movements during perception of complex objects. Nauka, Moscow, 1965. English Translation, New York: Plenum Press, 1967. Pp 171-211.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NAMRL-1247	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Influence of a Visual Display and Frequency of Whole-Body Angular Oscillation on Incidence of Motion Sickness		5. TYPE OF REPORT & PERIOD COVERED Interim 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Fred E. Guedry, Jr., Alan J. Benson, and H. Jack Moore		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Aerospace Medical Research Laboratory Naval Air Station Pensacola, Florida 32508		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ZF51.524.004-9022
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Medical Research and Development Command National Naval Medical Center Bethesda, Maryland 20014		12. REPORT DATE 22 June 1978 13. NUMBER OF PAGES 15
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Dr. Benson is Head of the Behavioral Sciences Division, RAF Institute of Aviation Medicine, Farnborough, Hants, England.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Motion sickness; Stimulus frequency; Visual-vestibular interaction; Vestibular function; Visual function.

+ou

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Visual search within a head-fixed display consisting of a 12 x 12 digit matrix is degraded by whole-body angular oscillation at 0.02 Hz (peak velocities ±155 deg/sec), and signs and symptoms of motion sickness are prominent in a number of individuals within a 5-minute exposure. Exposure to 2.5 Hz (±20 deg/sec peak velocity) produces equivalent degradation of the visual search task but does not produce signs and symptoms of motion sickness within a 5-minute exposure.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Guedry, F. E., Jr. 1978
A. J. Benson, H. J. Moore

INFLUENCE OF A VISUAL DISPLAY AND FREQUENCY OF WHOLE-BODY ANGULAR OSCILLATION ON INCIDENCE OF MOTION SICKNESS. NAMRL-1247. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 22 June.

Disadvantageous aspects of the vestibulo-ocular reflex may emerge in aircraft or other motion platforms when visual tasks center on displays that are fixed relative to the observer. In this circumstance the reflex may drive the eyes relative to the display, thereby degrading vision and sometimes inducing motion sickness. This report is one of a series of investigations elucidating stimulus conditions that influence the probability of nauseotypic disturbance during visual-vestibular interactions.

Visual search within a head-fixed display consisting of a 12 x 12 digit matrix is degraded by whole-body angular oscillation at 0.02 Hz (peak velocities ±155 deg/sec) and signs and symptoms of motion sickness are prominent in a number of individuals within a 5-minute exposure. Exposure to 2.5 Hz (±20 deg/sec peak velocity) produces equivalent degradation of the visual search task but does not produce signs and symptoms of motion sickness within a 5-minute exposure.

Motion sickness
Stimulus frequency
Visual-vestibular interaction
Vestibular function
Visual function

Guedry, F. E., Jr. 1978
A. J. Benson, H. J. Moore

INFLUENCE OF A VISUAL DISPLAY AND FREQUENCY OF WHOLE-BODY ANGULAR OSCILLATION ON INCIDENCE OF MOTION SICKNESS. NAMRL-1247. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 22 June.

Disadvantageous aspects of the vestibulo-ocular reflex may emerge in aircraft or other motion platforms when visual tasks center on displays that are fixed relative to the observer. In this circumstance the reflex may drive the eyes relative to the display, thereby degrading vision and sometimes inducing motion sickness. This report is one of a series of investigations elucidating stimulus conditions that influence the probability of nauseotypic disturbance during visual-vestibular interactions.

Visual search within a head-fixed display consisting of a 12 x 12 digit matrix is degraded by whole-body angular oscillation at 0.02 Hz (peak velocities ±155 deg/sec) and signs and symptoms of motion sickness are prominent in a number of individuals within a 5-minute exposure. Exposure to 2.5 Hz (±20 deg/sec peak velocity) produces equivalent degradation of the visual search task but does not produce signs and symptoms of motion sickness within a 5-minute exposure.

Motion sickness
Stimulus frequency
Visual-vestibular interaction
Vestibular function
Visual function

Guedry, F. E., Jr. 1978
A. J. Benson, H. J. Moore

INFLUENCE OF A VISUAL DISPLAY AND FREQUENCY OF WHOLE-BODY ANGULAR OSCILLATION ON INCIDENCE OF MOTION SICKNESS. NAMRL-1247. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 22 June.

Disadvantageous aspects of the vestibulo-ocular reflex may emerge in aircraft or other motion platforms when visual tasks center on displays that are fixed relative to the observer. In this circumstance the reflex may drive the eyes relative to the display, thereby degrading vision and sometimes inducing motion sickness. This report is one of a series of investigations elucidating stimulus conditions that influence the probability of nauseotypic disturbance during visual-vestibular interactions.

Visual search within a head-fixed display consisting of a 12 x 12 digit matrix is degraded by whole-body angular oscillation at 0.02 Hz (peak velocities ±155 deg/sec) and signs and symptoms of motion sickness are prominent in a number of individuals within a 5-minute exposure. Exposure to 2.5 Hz (±20 deg/sec peak velocity) produces equivalent degradation of the visual search task but does not produce signs and symptoms of motion sickness within a 5-minute exposure.

Motion sickness
Stimulus frequency
Visual-vestibular interaction
Vestibular function
Visual function

Guedry, F. E., Jr. 1978
A. J. Benson, H. J. Moore

INFLUENCE OF A VISUAL DISPLAY AND FREQUENCY OF WHOLE-BODY ANGULAR OSCILLATION ON INCIDENCE OF MOTION SICKNESS. NAMRL-1247. Pensacola, FL: Naval Aerospace Medical Research Laboratory, 22 June.

Disadvantageous aspects of the vestibulo-ocular reflex may emerge in aircraft or other motion platforms when visual tasks center on displays that are fixed relative to the observer. In this circumstance the reflex may drive the eyes relative to the display, thereby degrading vision and sometimes inducing motion sickness. This report is one of a series of investigations elucidating stimulus conditions that influence the probability of nauseotypic disturbance during visual-vestibular interactions.

Visual search within a head-fixed display consisting of a 12 x 12 digit matrix is degraded by whole-body angular oscillation at 0.02 Hz (peak velocities ±155 deg/sec) and signs and symptoms of motion sickness are prominent in a number of individuals within a 5-minute exposure. Exposure to 2.5 Hz (±20 deg/sec peak velocity) produces equivalent degradation of the visual search task but does not produce signs and symptoms of motion sickness within a 5-minute exposure.

Motion sickness
Stimulus frequency
Visual-vestibular interaction
Vestibular function
Visual function